Chemistry 103, Dr. Hamers
Help Sheet #5 - Chapter 4 (Part I)
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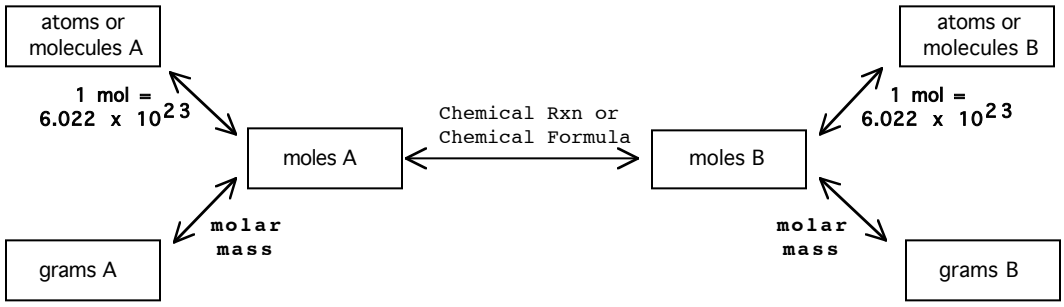
Nuggets: *Stoichiometric Calculations; Limiting reagents; Percent yield; Empirical Formulas determined from Combustion*

CHEMICAL EQUATIONS: reactants (the starting reagents) yield products (the ending materials)
Be able to balance chemical equations

STOICHIOMETRY: Given a chemical reaction and the quantity of one of the reagents in the equation, be able to determine the quantities of all the other reagents in the reaction.



LIMITING REAGENTS: one reagent runs out first; this is the limiting reagent

PERCENT YIELD = $\frac{\text{actual yield}}{\text{theoretical yield}}$ x 100% where actual yield is the actual amount obtained (must be given to you) and theoretical yield is a calculated amount. If percent yield > 100% then something has been missed (e.g., the sample may be wet, etc.)

EMPIRICAL FORMULA from mass CO_2 and H_2O/chemical analysis

A. Compound contains C and H only
1. Convert gCO_2 → mol CO_2 → **mol C**
2. Convert gH_2O → mol H_2O → **mol H**
3. Write formula and divide by smallest moles
4. If needed, fractions: $^1/_2$ (0.5) → x 2; $^1/_3$ or $^2/_3$ (0.33, 0.66) → x 3; $^1/_4$ or $^3/_4$ (0.25, 0.75) → x 4

B. Compound contains C, H, and O
1. Convert gCO_2 → mol CO_2 → **mol C → gC** (need both mol C *and* gC)
2. Convert gH_2O → mol H_2O → **mol H → gH** (need both mol H *and* gH)
3. Calculate gO from: total g sample = gC + gH + gO (gO = total g sample - gC - gH)
4. Convert O → **mol O**
5. Write formula and divide by smallest moles
6. If needed, fractions: $^1/_2$ (0.5) → x 2; $^1/_3$ or $^2/_3$ (0.33, 0.66) → x 3; $^1/_4$ or $^3/_4$ (0.25, 0.75) → x 4

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1. An oxide of tungsten (chemical symbol W) is a bright yellow solid. If 5.34 g of the compound contains 4.23 g tungsten, what is its empirical formula?

2. Copper metal reacts with nitric acid. Assume that the reaction is

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

a. If 10.00 g $Cu(NO_3)_2$ is obtained, how many grams of nitrogen monoxide, NO, would have also formed?

b. How many grams of water would also have formed?

3. Given the reaction: $4Cr + 3O_2 \rightarrow 2Cr_2O_3$, how many grams of O_2 will react with 1.00 mole of chromium?
a. 0.75 b. 24.0 c. 48.0 d. 42.7 e. 12.0

4. 15.0 grams of a metal carbonate, $M_2(CO_3)_3$ is heated and converted into MO and CO_2 producing 6.787 grams of CO_2. $M_2(CO_3)_3 \rightarrow M_2O_3 + 3CO_2$ The metal, M, is

5. Acrylonitrile, C_3H_3N, is the starting material for the production of a kind of synthetic fiber (acrylics). It can be made from propylene, C_3H_6, by reaction with nitric oxide, NO.

$$4C_3H_6(g) + 6NO(g) \rightarrow 4C_3H_3N(l) + 6H_2O(l) + N_2(g)$$

How many grams of acrylonitrile, C_3H_3N, are obtained from 651kg of propylene, C_3H_6, and excess NO?

6. When 9.20g of C_2H_6O are reacted with 40.6g of PBr_3, what mass of C_2H_5Br is produced?

$$3C_2H_6O + PBr_3 \rightarrow 3C_2H_5Br + H_3PO_3$$

7. If 75.0g of SiO_2(s) and 30.0g C(s) react according to the equation below, what is the maximum number of moles of CO that can be produced? $SiO_2 + C \rightarrow CO + SiO$
a. 1.25 b. 1.67 c. 2.25 d. 2.50 e. none of these

8. Use the following reaction to answer the following questions

$$3C_2H_6O + PBr_3 \rightarrow 3C_2H_5Br + H_3PO_3$$

46 (14.86) 270.7 (12.11) 82

a. 25g of C_2H_6O and 40.0 grams of PBr_3 are combined. How many grams of phosphorous acid can theoretically be produced in this reaction?
b. Which is the limiting reagent?
c. How many grams of the excess reagent are **unused**?
d. If 5.85g of phosphorous acid were recovered, what is the percent yield?

9. Given the reaction $3Ca + N_2 \rightarrow Ca_3N_2$ if 7.55g Ca and 22.5g N_2 react
a. What is the theoretical yield in grams of Ca_3N_2?
b. Which is the limiting reactant in the reaction?
c. Which is the excess reactant?
d. What mass of the excess reagent remains at the end of the reaction?
e. If 5.75g of Ca_3N_2 were recovered, what is the percent yield of the reaction?

10. Given the reaction $2C_3H_6 + 9O_2 \rightarrow 6CO_2 + 6H_2O$ if 30.75g C_3H_6 and 45.85g O_2 react
a. What is the theoretical yield in grams of CO_2?
b. Which is the limiting reactant in the reaction?
c. What mass of the excess reagent remains at the end of the reaction?

11. When 20.0g of HCl is reacted with 25.0g of Zn, hydrogen gas and zinc(II) chloride are produced. If 0.250g of hydrogen gas is recovered, what is the percent yield? (Hint: First write the balanced reaction.)

12. When a compound containing carbon and hydrogen is combusted, 3.38g CO_2 and 0.692g H_2O are recovered. a. What is the empirical formula? b. The MW of the compound is 78 g/mol. What is the molecular formula? (Use $AW_C = 12$ g/mol and $AW_H = 1$ g/mol)

13. When 5.00 g of a compound containing carbon, hydrogen, and oxygen is combusted, 8.911g CO_2 and 3.648g H_2O are recovered. a. What is the empirical formula? b. The MW of the compound is 74 g/mol. What is the molecular formula?

14. A 25.00g mixture of sodium oxide, Na_2O, and sodium carbonate, Na_2CO_3, is placed in a crucible and heated. When heated, the Na_2CO_3 gives off CO_2 and forms Na_2O, with the new mass in the crucible after heating being 18.77g. The original Na_2O in the crucible is unchanged during the heating process. What was the mass percent of Na_2O in the *original mixture* before the sample was heated.

15. A 15.00g mixture of ammonium sulfate, $(NH_4)_2SO_4$, and iron(III) sulfate, $Fe_2(SO_4)_3$, is placed in a crucible and heated. When heated, the $(NH_4)_2SO_4$ gives off NH_3 and forms H_2SO_4 which remains in the crucible. The new mass after heating was 11.91g. What was the mass percent of $Fe_2(SO_4)_3$ in the original mixture before the sample was heated.

ANSWERS

1. WO_3
2. a. 1.06 g NO b. 1.28 g H_2O
3. b
4. Fe {Need to determine AW of M; to do this you need g M and mol M;
   mol M: 6.787g CO_2 x (1mol CO_2/44g CO_2) x (1mol $M_2(CO_3)_3$/3mol CO_2) x (2mol M/1mol $M_2(CO_3)_3$) = 0.103mol M;
   g_{total} = g M + g CO_3; find g CO_3; 6.787g CO_2 x (1mol CO_2/44g CO_2) x (3mol CO_3/3mol CO_2) x (60.01g CO_3/1mol CO_3) = 9.257g CO_3; gM = 15.0 – 9.257 = 5.74g M; AW_M = 5.74g M/0.103mol M = 55.76g/mol → Fe}
5. 822,000 g C_3H_3N
6. 21.8 g C_2H_5Br
7. a
8. a. 12.1g H_3PO_3 b. PBr_3 c. 4.61g C_2H_6O d. 48.3%
9. a. 9.31g Ca_3N_2 b. Ca c. N_2 d. 20.7g N_2 left over e. 61.8%
10. a. 42.03g CO_2 b. O_2 c. 17.38 C_3H_6 left over
11. 45.2% ($Zn(s) + 2HCl(g) \rightarrow ZnCl_2(s) + H_2(g)$)
12. a. CH b. C_6H_6
13. a. $C_3H_6O_2$ b. $C_3H_6O_2$
14. 40.0%
15. 20.0%